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Effect of Plant Growth Regulators and Different Agronomic Practices on Carnation (Dianthus caryophyllus) Cultivars Growth and Quality Parameters:A Term Paper

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Abstract
Different research works on different treatment were reviewed to see the effects on growth parameters (Plant height, node number and inter nodal length, stem girth, shoots number, number of leaves, length of shoot, length of leaf), flowering parameters (number of days for bud initiation, number of days for flower development and length of flowering),flower quality parameters(lower Stalk length, flower diameter, flower length, flower weight, vase- life) and yield parameter(flower numbers per plant) which are important aspects that influence on costumers preference on carnation cut flower. The review paper found that appropriate growth regulators in combination with best agronomic practice are the two main components to produce quality carnation produce

Introduction

Carnation is preferred to roses and chrysanthemums by several exporting countries, on account of its excellent keeping quality, wide range of forms and colours and ability to withstand long distance transportation. Cut carnations, roses and chrysanthemums contribute close to 50% of the world cut flower trade Kiss Zs *et al*.(2001).

Carnation belongs to the family Caryophyllaceae. The genus name 'Dianthus' is derived from the Greek words 'dios' meaning 'God' or 'divine' and 'anthos' meaning 'flower' and hence known as 'Divine Flower'. The species name 'caryophyllus' is derived from the Greek word 'caryan' meaning 'nut' and 'phyllon' meaning 'leaf'. The name 'caryophyllus' has been chosen by Linnaeus after the genus name of clove, due to the clove-like fragrance of carnation. The common name 'carnation' probably must have come from the Greek word 'coronation' because these flowers were used in decorating the crown of Greek athletes. Carnation is the national flower of Spain arrangement Kiss Zs *et al* (2001).

Carnations are excellent for cut flowers, bedding, pots, borders, edging, indoors and rock gardens. They give a unique softness to the rock gardens. Though cut carnations are traded in the world market year round, they are in particular demand for the Valentine's Day, Easter, Mother's Day and Christmas. Miniature carnations are now gaining popularity for their potential use in floral arrangement Kiss Zs et al (2001).

Plant growth regulators (PGRs) are organic compounds, other than nutrients, that modify plant physiological processes. PRGs, called biostimulants or bioinhibitors, act inside plant cells to stimulate or inhibit specific enzymes or enzyme systems and help regulate plant metabolism.

They normally are active at very low concentrations in plants *Charles and Edward (1914).*

The importance of PGRs was first recognized in the 1930s. Since that time, natural and synthetic compounds that alter function, shape, and size of crop plants have been discovered. Today, specific PGRs are used to modify crop growth rate and growth pattern during the various stages of development, from germination through harvest and post-harvest preservation. Growth regulating chemicals that have positive influences on major agronomic crops can be of value. The final test, however, is that harvested yields must be increased or crop quality enhanced in order for PGRs to be profitable *Charles and Edward (1914).*

Objectives

To review the effect of growth regulators on carnation shoot and root initiation

To review different agronomic practices influencing on growth performance, yield quality and vase life of carnation cut flower

Literature Review

Effect of plant growth Regulators on shoot regeneration

Mahdiyeh et al.(2011) conducted a study to evaluate the effect of plant growth regulators on *in vitro* shoot multiplication, vitrification and rooting of two carnation cultivars (Eskimo Mogr and Innove Orange Bogr The results of this experiment showed that there was a significant difference between two cultivars in shoot regeneration. In addition, plant growth regulators significantly influenced the proliferation and vitrification of regenerated shoots. In all treatments, Eskimo Mogr produced more shoot than Innove Orange Bogr (2.94 and 1.97, respectively). Also two carnation cultivars had the same reaction to the different types of cytokinin. Medium containing BAP was more effective than Kin on shoot regeneration.The highest number of shoots (5 shoots/explant) was formed on medium supplemented with 4 mg/l BAP compared to 0.69 shoot on basal mediumBut shoot regeneration in different levels of Kin was nearly constant (1.18 shoots/explant). In most concentrations of

cytokinins, Kin led to produce longer shoots in compare with BAP and as the level of cytokinins increased, the height of shoots decreased (Fig. 1-A). As regards BAP induces the loss of apical dominance and accelerates the growth of lateral buds, it seems that increasing the concentration of this growth regulator induces the growth of axillary buds.The results of previous studies have shown that application of cytokinin stimulated sprouting and development of higher number of axillary buds and apical dominance release was suppressed with the increase of cytokinin concentration (Kapchina-Toteva and Yakimova 1997). In addition, shoot height and internode length tended to decrease with increasing cytokinin concentration (Brar et al. 1995). These results are in close agreement with our findings.Ali et al. (2008) reported that the media supplemented with BAP produced more shoots than Kin. They also reported that using Kin in the medium caused the regeneration of longer shoots, in comparison with BAP. Brar et al. (1995) found that increasing the concentration of cytokinin led to decreasing the height o regenerated shoots and by increasing the level of cytokinin, the rate of regeneration increased. While, Majib and Pal (1995) reported that among the various concentration of BAP, the lowest amount of it (0.5 mg/l) caused the highest number of shoots per explant. Our results are similar to Ali et al. (2008) and Brar et al.(1995) reports but in contrast to the finding of Mujib and Pal (1995). Since they reported that among the various concentration of BAP, the lowest amount of it (0.5 mg/l) caused the highest number of shoots per explant. This contradiction may be due to different cultural condition or genotype.on the medium supplemented with 0.5 mg/l NAA, while for Innove Orange Bogr (98%) it was obtained on the medium

Kiss zs et al (unknown year) conducted an experiment related to investigation of the in vitro regeneration of mericlones in the caribe variety of carnation For the induction of callus formation in the in vitro cultures using the in vítro cultures were started from shoot apical meristems with a diameter of about 2 mm, isolated under axenic conditions and inoculated on sterile Murashige-Skoog (MS) nutrient medium -eelified with agar.agar Í4,7). The control was grown on pure MS medium, while the other experimental variants contained the following developmental stimulators:

a) 4 pM benzyladenin(eB A), i.e.a synthetic ytokinin

b) 0.5 prM naphtylacetica cid (NAA. a syntherica uxin;, 0.5 prM kinetin (K, a cytokinin) and 100 mg l-l kazein (Kaz) as an organic nitrogen source, added to a IvtS medium without B -type vitamins,in ositola ndg lycin

c) 2 pM gibberelic acid (GA3), 3 pM indolebutiric acid (lBA, a synthetic auxin) arld 5 pM BA.For the induction of callus formation in the in t,itro cultures, the MS medium was supplemented with the fol Io w in g amo un ts of 2,4- dichlorophenoxiaceti c acrd(Z,LD as a synthetic auxin also used as a herbicide) and benzyladenine, 0.5 mg/ litr 2,4-D+ 2.0 mg/litr BA, 1.0 mg/ litr 2,4-D+ 1.5 mg /litr BA, 1.5 mg/ litr 2,4-D+ 1.0 mg /litr BA, 2.0 mg/ litr 2,4-D+ 0.5 mg /litr BA.

The shoot growth of the mericlones regenerated from the apical meristem was almost doubled compared to the control on the culture medium enriched with a combination of gibberelin (GA3), auxin (IBA) and cytokinin (BA). This supplementation with micromolar amounts of external growth stimulators, interacting with the endogenous hormones produced by the plant cells, resulted in a very significant enhancement of cell divisions and elongation processes. The benzyladenine together with the cytokinin produced in the meristematic cells, stimulated the rate of mitotic process, while the interaction of auxins and gibberelic acid led to an enhanced cell elongation in the internodes of the stem and in the developing young leaves.This means that under these conditions the new plantlets grow much faster, they reach maturity and produce flowers in a much shorter period of time. Addition to the MS medium of benzyladenine alone results in a moderate stimulation of shoot growth, while the development of the regenerated mericlones is inhibited by around 507o in the absence of B-type vitamins, even if the nutrient medium was supplemented with exogenic auxin (NAA), citokynin (K) and kazein.Gallus formation occured in different degrees on the culture media. It was most intense on the MS medium.It has to be mentioned that callus formation is a positive phenomenon if one intends to initiate new individual varieties by means of somaclonal variability, but it is an undesirable side-event if the goal is to obtain more descendants that have to be identical with the formerly selected mother plant [1, 3, 9].Root formation was not stimulated by either of the experimental setups and it was mostly inhibited by addition of 4 pM benzyladenine as an extra amount of cytokinin. This results can be explained by the fact that the ratio between total auxin and cytokinin concentrations in the cells was modified in favor of the cytokinins, which stimulate caulogenetic regeneration, while rhyzogenesis needs a higher auxin: cytokinin ratio [8].T he sli_ehtesitn hibition of root formation was observed in the medium supplemented with the combination of 2 pM GA3, 3 ttM IBA and 5 pM BA.

Influence of growth regulators on morphogenetic processes under in vitro condition

Lapadatescu etal.(2012) studied influence of growth regulators on morphogenetic processes under *in vitro* condition. The phytohormones show significant influence on the process of plantlets neo formation, occurring differences statistically assured. Thus, the highest values were recorded when applying the culture medium of auxines: ANA(94,97), 2,4-D(91,23) and 2,4 D/KIN(90,77) , while the lowest values were obtained for the use of GA3 and KIN. Regarding phytohormones influence on proliferative capacity, citokinines (BA, KIN) showed the highest values of number of sprouts/seedlings, showing strong differences statisticly provided from the results

obtained using auxines (2,4-D, AIA, ANA, AIB). Given the unilateral effects of hormones is observed that statistically assured there are differences between them regarding plantlets vitrification. Thus, the highest values were recorded when applying the culture medium of citokinines: KIN and BAP while auxinele led to a reduction in the vitrification process. Increasing concentrations of phytohormones in the culture medium caused a proportionate increase in the percentage of plantlets that have evolved towards vitrification. Supplementing MS culture medium with phytohormones, regarding of concentration used, determinated an increase in the vitrification process of plantlets.

Kanwar and S. Kumar (2009) worked on the influence of growth regulators, explants and their interactions on *in vitro* shoot bud formation from callus was studied in *Dianthus caryophyllus* L. The leaf and internode explants were cultured on Murashige and Skoog (MS) medium containing different concentrations of growth regulators. The highest callus induction was observed with 2 mg/l 2,4-dichlorophenoxy acetic acid (2,4-D) and 1 mg/l benzyl adenine (BA). Out of twenty seven shoot regeneration media tested, only 2 mg/l thidiazuron (TDZ) and zeatin alone or in combination with naphthalene acetic acid (NAA) and/or indole acetic acid (IAA) could differentiate calli. The highest average number of shoots was observed with 2 mg/l TDZ and 1 mg/l IAA . Significant differences were observed in calli producing shoots and number of shoots per callus in the explants of leaf and internode. The shoots were elongated and multiplied on MS medium supplemented with 1 mg/l BA and solidified with 1% agar. The shoots were rooted and hardened with 76% survival success in pots after six weeks of transfer to the pots.

Effect of Different Agronomic practices on the Growth of Carnation Cut flower

Growth parameters

Plant Height

Singh *et al*. (1994) studied the effect of summer shading on the plant growth and flower production on standard Carnation cultivar „Espana‟ under different shading treatment (0 or control, 25 and 50%) shading. The maximum (54.47 cm) plant height was recorded in 25% shade treatment. The minimum (49.42 cm) plant height was recorded in control check. Lal *et al.* (1998) reported that the variety „Scania‟ attained maximum plant height (59.46 cm), followed by „Shocking Pink‟ (59.51 cm). The varieties „Tangerine‟ (52.67 cm), „Harvest Moon‟ (53.06 cm) and „Yellow Dusty‟ (53.3 cm) had smaller plants among the standard types. The maximum plant height (62.10 cm) was recorded under un pinched and the lowest one (39.27 cm) when the plants were pinched twice. Kumar and Singh (2003a, 2003b) studied Carnation cultivar „Red Corso‟ under screen house for three planting seasons viz., early, mid and late and two day lengths conditions, viz., short and long day in all possible combinations. Plant height was maximum (86.65 cm) in autumn season. In interaction effect, autumn season and long day condition showed maximum plant of 93.36 cm. Dwivedi and Kareem (2004) evaluated 15 varieties of Carnation under cold arid region of India and revealed that average plant height varied from 47.65 cm and 57.66 cm in „New Espana‟ and „Arthur Sim‟, respectively. Under partially modified greenhouse condition, Gurav *et al*. (2004) standardized the package of practices for Carnation cultivar Sunrise and recorded maximum plant height (60.16 cm) at first harvest in treatment (soil + compost + sand at ratio 2:1:1 substrate and 40 KPa irrigation regime, basal dose as 200:200:100 NPK Kg/ha/year + 100 kg N/ha/year + 200 kg K/ha/year through fertilization. According to Reddy *et al*. (2004), cultivar „Alma‟ recorded maximum plant height (110.55 cm), followed by „Sugar Baby‟ (110.32 cm), „Pirandello‟ (107.16 cm) and „Candy‟ (102.50cm), whereas cultivar „Leon‟ recorded minimum plant height of 83.74 cm. Height of plant was medium in varieties Denton, Desio and Madame Collette (98.83 cm, 96.91 cm and 94.15 cm, respectively) grown under low cost polyhouse conditions.

Node number and inter nodal length

Sawwan and Samawi (2000) observed that double pinch after six weeks of planting significantly reduced number of nodes per flowering stem. Maximum number of internodes per branch recorded in cultivar „Desio‟ (18.86) and the minimum in cultivar „Leon‟ (13.45). The internodal length was maximum in cultivar „Pirandello‟ (6.89 cm) and was minimum (4.65 cm) in cultivar „Desio‟ (Patil 2001). Shiragur *et al.* (2004b) reported that number of internodes per stem was maximum in cultivar „Madame Collette‟, „Alma‟, „Sugar Baby‟ and „Desio‟ (20.38, 19.54, 19.28 and 18.48, respectively). However, it was minimum (15.69) in cultivar „West Pretty‟. Cultivar „Sorisso‟, „Madame Collette‟, „Pirandello‟ and „Aicardi‟ had maximum internodal length (5.71 cm, 5.69 cm, 5.4 cm and 5.18 cm, respectively) while it was minimum in cultivar.

Stem girth

Atanassova and Batchvrova (1995) obtained maximum stem girth at base of (6.0 mm) on cultivar „Yanita and the second cultivar „Krassina‟ (5.6 mm) and cultivar „Red Barbara‟gave minimum girth and stem of 4.5 mm. Patil (2001) reported that Maximum stem girth (5.99 mm) was found in cultivar „Madame Collette and minimum stem girth (3.83 mm) was recorded in cultivar „Leon‟. Based on Shiragur *et al.* (2004b), among the varieties evaluated under polyhouse condition, cultivar Sugar Baby, Madame Collette, Alma and West Pretty had thicker and strong stem (7.14 mm, 6.88 mm, 5.98 mm and 5.16 mm, respectively), while cultivar „Sorisso‟ had weak stem of 3.53 mm.

Shoots number

Sathisha (1997) conducted trail in a greenhouse and revealed that variety „IAHS-7" had a highest number of branches (13.75), followed by „IAHS-27" (10.25) whereas, variety „IAHS-5" had minimum number branches (6.70). Patil (2001) wrote that the variety „Madame Collette" recorded maximum number of branches (4.52), followed by „Desio" (4.35) and „Alma" (4.22), whereas „Leon" recorded minimum number of branches (2.85) at 180 days after plantation. Kumar and Singh (2003) reported relatively higher number of branches (8.58) in autumn planting in Carnation. Shahakar *et al.* (2004) studied the growth, flower quality and yield a of Carnation varieties under polyhouse condition and shown that „Cobra" recorded significantly superior result in respect of number of shoots per plant (5.80) and it was followed by „Gaudina", „Super Green", „Niva" and „Salsa". Minimum number of shoot was observed in „Montezuma" (4.25). In a greenhouse trial on Carnation conducted by Shiragur *et al.* (2004b), further number of shoots were exhibited by the varieties „West Pretty" (7.81), „Desio" (7.14), „Aicardi" (6.96) and „Candy" (6.64); whereas the cultivar „Sugar Baby" has its lowest value (5.25). Singh *et al.* (2006) reported 7.4 side shorts per plant under natural day length, whereas, in 4 h and 6 h additional light the number of side shoots were 7.3 and 7.0 respectively. H. Salehi (2006) conducted an investigation to find the best shoot proliferation and rooting media for 13 virus free cultivars of carnation (*Dianthus caryophyllus* L.) The best shoot proliferation media were Murashige and Skoog (MS) containing 3 mgL-1 (13.95 M) kinetin and 0.5 mgL-1 (2.69 M) NAA or 1 mgL-1 (4.44 M) BA and 1 mgL-1 (5.37 M) NAA. ,It can be concluded that using the MS medium supplemented with 1 mgL-1 BA (4.44 M) and NAA (5.37 M) for shoot proliferation of used carnation cultivars is possible. In this medium, the used cultivars produced about 1 to 8 shoots in their subcultures, with a mean of about 4 shoots. This general medium can be used easily for commercial multiplication of virus-free carnation plants. According to the results, rooting medium in used carnation cultivars is highly genotype dependent and can not recommend a general medium for rooting all of them.

Number of leaves

Naveenkumar *et al.* (1999b) studied the effect of growing environment on flowers of Carnation and the study revealed that cultivar „Red Corso" and „Cabaret" under polyhouse recorded 27 and 23 leaf pairs at flowering, respectively.Patil (2001) stated that the number of leaves produced per plant was maximum in cultivar „Madame Collette" (204.80), followed varieties „Alma" (194.82) and „Candy" (184.67) and was minimum in cultivar „Leon" (129.54) at 180 days after planting plants under low cost polyhouse. Kumar and Singh (2003a, 2003b) reported relatively higher number of leaves (209.47) was observed in autumn planting. Plant grown under short days at winter recorded 215.03 leaves. However, in case of interaction effect, the maximum number of leaves (224.71) was recorded under autumn planting season with short day length. Under low cost polyhouse condition, cultivar „Madame Collette" produced maximum number of leaves per plant (184.10), followed by „Candy" (180.74) and „Alma" (172.28), whereas minimum (110.29) was recorded in cultivar „Leon" (Reddy *et al.* 2004). Among the six Carnation varieties evaluated under polyhouse, maximum number of leaves was recorded in cultivar „Gaudina" (93.76), whereas minimum (67.10) was recorded in cultivar „Niva" (Shahakar *et al.* 2004). Shiragur *et al.* (2004b) studied the performance of standard Carnation varieties under protected cultivation and study revealed that the number of leaves produced per plant was maximum in cultivar „Madame Collette" (208.97), „Aicardi" (204.03), „Candy" (203.87) and „Alma" (198.73), while „Sorisso" produced lesser number 4 leaves (165.47).

Length of shoot

Patil (2001) showed that the maximum shoot length was observed in cultivar „Alma" (114.45 cm), followed by cultivar „Sugar Baby" (111.65 cm) and minimum shoot length was observed in „Leon" (70.87 cm) at 180 days after planting under low cost polyhouse condition. Singh *et al.* (2006) reported that the long days enhanced internodal length shoots and *Tah and Mamgain* 14 hence, produced longer flowering stems. The extended photoperiod resulted in longer flowering stem (69.9 cm and 67.8 cm under 4 h and 6 h additional light, respectively) over the control (50.2 cm).

Length of leaf

Kamble (2001) saw the carnation cultivar „Trust" had recorded maximum leaf length (53.31 cm), while cultivar „Melody" recorded minimum (42.67 cm) at 60 days after planting. The cultivar „Madame Collette" recorded maximum leaf length (13.12 cm), whereas cultivar „Leon" recorded minimum leaf-length (7.29 cm) grown under low cost poly house (Patil 2001). Shiragur *et al.* (2004b) studied the performance of standard carnation varieties under protected cultivation and reported that leaf length was maximum in varieties „Madame Collette", „Pirandello", „West Pretty" and „Aicardi" (10.88 cm, 10.30 cm, 10.04 cm and 8.78 cm, respectively); while cultivar „Sorisso" recorded the minimum leaf length of 6.03 cm.

Flowering Parameters

Number of days for bud initiation

Naveenkumar *et al.* (1990b) observed that cultivar „Red Corso" was early in flowering (138 days after planting) when compared to „Cabaret" (162 days after planting). Bhautkar (1994) studied the performance of 10 varieties under greenhouse and reported that cultivar „Barbara" was the earliest to initiate following 10th days after planting. However, cultivar „Eveline" was late which required 119 days for the bud initiation. Satisha (1997) reported that

early flower bud initiate was recorded in cultivar „IAHS -22" (95.75 days), followed by cultivar „IAHS- 23" (96.30 days). Patil (2001) studied 10 Carnation varieties under low cost polyhouse and reported that cultivar „Leon" was earliest to initiate flowering (55 days), whereas cultivar „Aicardi" was too late that took 128.67 days for flower bud initiation. Kumar and Singh (2003a, 2003b) reported that the maximum number of days (102.94) for flower bud emergence was taken by autumn planting whereas further delay in planting led to early emergence of flower bud. The earliest bud emergence (85.65 days) was observed in the late winter season. The plants exposed to long day condition took the least number of days for their bud emergence (78.5%). In case of interaction effect the earliest bud emergence (71.61 days) was observed in late winter season with long days. An experiment was carried out to study the performance of 10 Carnation varieties by Reddy *et al.* (2004). According to them, the flower bud initiation was earlier in cultivar „Leon" (55 days), followed by „Sorisso" (71 days) and „Desio" (72 days). Late flowers were observed in varieties „Aicardi", „Pirandello" and „Candy" (128, 120.67, 114.66 days respectively

Number of days for flower development

Patil (2001) assessed 10 varieties under low cost polyhouse and reported that cultivar „Alma" took very less time for bud development (18.00 days), whereas cultivar „Sorisso" took more time (26.33 days) for development of flower bud. Shiragur *et al.* (2004a) observed that cultivar „West Pretty" took less time for bud development (17.67 days), followed by „Sugar Baby" (18.00 days); whereas cultivar „Sorisso" was late in bud development (29.33 days) when cultivars were evaluated under low cost polyhouse

Length of Flowering

Lal *et al.* (1998) studied the performance of different variation of Carnation and noted that the longest duration of flowering (31.5 days) was observed in the variety „Sims Pride" which is a spray type, followed by the standard type „Scania" (31.03 days). Patil (2001) reported that the flowering period was maximum in cultivar „Desio" (188.67days) and was minimum in cultivar „Aicardi" (143.33 days). Dwivedi and Kareem (2004) evaluated the fifteen Carnation varieties and noted that the longest duration (34.3 days) was observed in the variety „Flair", followed by 33.0 days in „Etora". „Red Carnation" variety had shortest duration of flowering (26.65 days). Shiragur *et al.* (2004a) examined the standard Carnation cultivar under protected cultivation and reported that as far as flower duration is concerned; cultivar „Aicardi" (235.0) recorded maximum duration, followed the „Alma" (229.67), „West Pretty" (222.67), „Candy" (222.0) and „Sugar Baby" (218.67), whereas varieties „Pirandello" (184.67), „Desio" (184.67) and „Sorisso" (193.33) recorded minimum duration.

Flower Quality parameters

Flower Stalk length

Dwivedi and Kareem (2004) published that cultivar „Dusty Pink" showed maximum flower stalk length of 27.00 cm whereas it was more in cultivar „Cabaret" (19.65 cm). An experiment was carried out by Reddy *et al.* (2004) to study the vegetative growth, flower yield and quality of ten standard Carnation varieties under law cost polyhouse condition. The study revealed that the length of flower stalk was longest in „Alma", „Sugar Baby", „Aicardi" and „Pirandello" (95.92, 93.63, 89.85 and 89.15 cm. respectively). Moderate flower stalk length was recorded in „Desio", „Candy" and „Madame Collette" (88.68, 87.54 and 85.76 cm, respectively.The study revealed that maximum stem length was observed in cultivar „Ga.udina" (93.94 cm) and it was minimum in cultivar „Niva" (68.26 cm). Study conducted under low cost polyhouse by Shiragur *et al.* (2004a) found that, maximum stalk length was recorded in cultivar „Pirandello" (91.02 cm) followed by cultivar „Candy" (87.74 cm); whereas minimum stalk length was recorded in cultivar „Desio" (67.88 cm). The maximum flower stem length (52.10 cm) was found under single pinching and minimum (39.5 cm) under double pinching. In case of interaction effect the maximum flower stalk length (58.4) was recorded in single pinching and 500 ppm nitrogen (Singh and Singh 2005). Singh *et al.* (2006) noted that the extended photoperiods resulted in longer flower stem (69.9 cm and 67.8 cm under 4 hour and 6 hour additional light, respectively) over the control (50.2 cm).

Flower Diameter

Singh *et al.* (1994) observed maximum bloom size (8.4 cm) in cultivar „Scania", whereas it was minimum (96.7) cm in cultivar „Can Can". According to Atanassova and Batchvarova (1995), the diameter of flower was maximum in „Biliand" and „Red Barbariz" (4.5 cm), whereas it was minimum (4.3) in „Yanita". Naveenkumar *et al.* (1999a) reported that flower diameter ranged between 6.83 cm in cultivar „Red Corso" to 5.40 cm in „Cabaret". Patil (2001) noticed that cultivar „Madame Collette" had maximum flower diameter (6.63 cm) followed by cultivar „Alma" (6.31 cm), whereas cultivar „Leon" had minimum flower diameter of 4.13 cm. Flower diameter was maximum (6.98 cm) in no pinched plants. However, it was minimum 5.60 cm in case of double pinched plants (Pathania *et al.* 2000). Singh and Sangama (2003) noted that there was significant variation among the varieties evaluated. The maximum flower diameter of 6.08 cm was recorded in cultivar „Aicardi" followed by „Sunrise" (5.61 cm). The flower diameter was minimum in „Lilac Torres" (4.25 cm). Dwivedi and Kareem (2004) reported that diameter of flower showed no significant variation and it ranged from 5.0 cm in „White Candy" to 5.9 cm in „Shocking Pink", „Atora" and „Carpalmor.Among nine varieties grown under low cost polyhouse, cultivar „Candy" recorded maximum flower diameter (6.63 cm) followed by „Madame Collette" (6.41 cm), whereas cultivar „Sorisso"

recorded minimum flower diameter of 5.63 cm (Shiragur *et al.* 2004a). The maximum flower diameter (5.7 cm) was obtained in single pinching and was least (5.2 cm) in double pinching, whereas in case of interaction effect it was maximum in (5.8 cm) in single pinching with 200 ppm nitrogen and single pinching with 500 ppm nitrogen (Singh and Singh 2005). Singh *et al.* (2006) noted that maximum flower diameter (6.61 cm) was noticed under 4 h additional light, whereas it was minimum (5.76 cm) under natural day length.

Flower length

Bhautkar (1994) reported that the maximum length of flower (7 cm) was recorded in varieties „White Sim", „Lena" and „Arthur Sim", whereas minimum (4.5 cm) was recorded in „Starlight" under glasshouse. Gurav *et al.* (2004) evaluated Carnation cultivar „Sunrise" under partially modified greenhouse and revealed that the flower length was found to be maximum (5.36 cm) in treatment M4 (Soil + compost + Sand (2:1:1) substrate, 20 KPa irrigation fertilization + basal dose at 200: 200:100 NPK kg/ha/yr + fertilization through straight fertilizers), whereas it was recorded minimum of 4.45 cm.

Flower weight

Singh *et al.* (1994) saw no significant difference in final cut-flower weight. It was maximum (28.82 g) in no shade whereas minimum (28.02 g) in 50% shade treatment for second flush. Krishnappa *et al.* (2000) reported significant differences in cumulative fresh weight of flowers. Significantly highest cumulative fresh weight (148.28 g) was recorded in cultivar „Aleda"; whereas minimum cumulative fresh weight of flower was recorded in cultivar „Vienna" (104.96 g). Singh *et al.* (2001) studied different varieties and noticed that cultivar „Forca" recorded higher fresh weight (28.73 g) followed by „Tasman" (20.16 g) and „Aicardi" (19.53 g) and lowest weight was observed in „Lillac Torres" (10.10 g). Cultivar „Pentara" and „Sunrise" recorded better fresh weight with the incorporation of silver nitrate + Sucrose + 8- Hydroxyquinoline as reported by Chikkasubbanna and Sharada (2002). Shiragur (2002) studied the performance of Carnation varieties under polyhouse condition and reported that „Madame Collette", „Sugar Baby", „Aicardi", „Alma" and „Pirandello" recorded higher flower weight (16.42, 15.83, 13.92, 13.43, and 13.83 g, respectively), while cultivar „Sorisso" recorded minimum flower weight of 8.42 g. Singh and Sangama (2003) reported that „Forca" had highest fresh weight of flower stalk (28.13 g) followed by cultivar „Tasman" (18.33 g). The minimum fresh weight of 11.96 g was obtained in „Lilac Torres". Among the difference Carnation varieties studied, cultivar „Madame Collette" recorded higher fresh weight (16.42 g) followed by „Sugar Baby" (15.83 g) and „Aicardi" (13.92 g) and lowest (8.42 g) in cultivar „Sorisso" (Shiragur *et al.* 2004a).

Vase- Life

Among ten varieties evaluated by Bhautkar (1994), varieties „Thalassa" and „Bianca" recorded maximum vase life (8 day each). However, „Arthur Sim" recorded minimum vase-life of 3 days. Singh *et al.* (1994) observed longer vase-life under unshaded plants for second flush Naveenkumar *et al.* (1999a) observed maximum vase-life (10.0) in cultivar „Cabaret", whereas it was minimum (8.67 days) in cultivar „Red Corso" under polyhouse when treated with 8-HQC 200 ppm. The maximum vase-life of 11.0 days was recorded in cultivar „Master", followed by cultivar „Kristina" (10.63 days); whereas cultivar „Vienna" recorded significantly shortest (9.74 days) vase-life (Krishnappa *et al.* 2000). Pathania *et al.* (2000) reported that the keeping quality of cut Carnations was higher (13.13 days) in case of un-pinched plants because of better availability of nutrition and accumulation of carbohydrates. Patil (2001) evaluated 10 Carnation varieties under polyhouse and noted significant difference in vase-life. Singh *et al.* (2006) noted that additional lighting did not affect vase life of the flowers. Singh *et al.* (2007) studied the effect of vase and pulsing solutions on keeping quality of standard Carnation cut flowers and reported that the vase-life of cut-flowers was maximum (11.45 days) in solution containing sucrose (5%) + aluminum sulphate (200 ppm). Among different combinations comprising of sucrose, biocides and ethylene antagonists, the maximum vase-life (13.44 days) was observed when the stems were pre-treated with STS, 1 mM under cool conditions for 24 h, followed by placing the stems in vase solution containing sucrose (5%) + aluminum sulphate (200 ppm). Among the pulsing treatments, maximum vase-life (11.89 day) was obtained with solution containing sucrose (10%) + aluminum sulphate (200 ppm) + STS (0.2 mM). According to Tejaswini and Murgod (2005) the vase-life was found to be highest (8.89 days) in case of flowers produced in molecule M4 (Sand: Soil: Compost as 1:2:1 + 6 lit/m2/day irrigation regimes + Straight fertilizers) and was least (7.33 days) in M1 (Sand: soil: compost 1:2:1 + 6 liter/m2/ day irrigation + water soluble fertilizers) in Carnation cultivar „Sunrise".

Yield Parameters

Flower numbers per plant

Bhautkar (1994) observed maximum number of flowers in cultivar „Eveline" (18) followed by cultivar „Furore" (17) and the cultivar „Starligtht" (16), whereas minimum number of flowers was recorded in cultivar „Lena" (10). Singh *et al.* (1994) noted that better flower yield was observed during the second lush that is in winter months. The maximum number of flowers per plant was harvested from 25% shade treatment (13.27 flowers). Atanassova and Batchvarova (1995) observed maximum number of flower per plant in cultivar „Nicki" (6.2), followed by

cultivar „Yanita‟ (6.0) and minimum in cultivar „Red Barbara‟. Gill and Arora (1998) recorded maximum number of flowers per plant in cultivar „Can Can‟ (6.7 flowers). Lal *et al.* (1998) studied the performance of fourteen varieties of Carnation and reported that higher numbers of flowers per plant were observed in spray variety „Sam‟s Pride‟ (11.2). However, among the standard varieties maximum numbers of flowers (5.1) were produced by the variety „Scania‟, followed by „Arthur Sim‟ (4.97) and „White Sim‟ (4.7). The variety „Tangerine‟ (4.13) produced lesser number of flowers per plant. Naveenkumar *et al.* (1999b) observed highest number of flowers per plant (7.75) in cultivar „Red Corso‟ under polyhouse as compared to lesser (4.5) flowers per plant under the open cultivation. Cultivar „Cabaret‟ recorded 6.25 flowers per plant under polyhouse as compared to 3.00 flowers per plant under open condition. Under low cost polyhouse, Patil (2001) evaluated 10 varieties of Carnation and recorded maximum number of flowers in cultivar „Madame Collette‟ (4.29), followed by cultivar „Desio‟ (4.13), while minimum number of flowers was recorded in cultivar „Leon‟ (2.71). Kumar and Singh (2003a, 2003b) observed maximum number of flowers per plant in autumn season of planting, whereas in case of interaction of effect of planting season and day length, the maximum number of flowers per plant was observed in autumn season of planting with long day length. Dwivedi and Kareem (2004) reported that the number of flowers per plant were maximum (6.3) in cultivar „Red Corso‟ whereas, it was recorded minimum in cultivar „New Espana‟ (4.3).

Summary

Carnation is preferred to roses and chrysanthemums by several exporting countries, on account of its excellent keeping quality. Carnation belongs to the family Caryophyllaceae. The genus name ‘Dianthus. Plant growth regulators (PGRs) are organic compounds, other than nutrients, that modify plant physiological process.The influence of growth regulators on *in vitro* show significant influence on the process of plantlets and root formation. The supplementation of external growth stimulators, interacting with the endogenous hormones produced by the plant cells, resulted in a very significant enhancement of cell divisions and elongation.

MS medium is general medium which can be used easily for commercial multiplication of virus-free carnation plants. Type of cultivation, type, method and amount of fertilizer application affects carnation with yield and growth performance and its vase life.

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